WRP Technical Note HY-DE-6.1
January 1993

Literature Review on the Use of Water-Stained Leaves in the Delineation of Wetlands

PURPOSE: The initial purpose of this review was to determine whether the scientific literature contains a technical basis for the use of water-stained leaves as a field indicator of wetland hydrology. When it was established that no technical information was available on the specific topic of water-stained leaves, the review was broadened to examine factors that could potentially influence the occurrence of water-stained leaves in wetland conditions. A table summarizing the habitat type, location, processes investigated, and environmental factors considered in each of the reviewed articles is presented. A synthesis of this literature, along with suggestions for the use of water-stained leaves in wetland identification, can be found in WRP Technical Note HY-DE-2.1.

BACKGROUND: Water-stained leaves were presented as a significant indicator of wetland hydrology in the 1989 Federal wetlands delineation manual, and currently are used as a secondary hydrologic indicator under the 1987 Corps of Engineers manual. In spite of this emphasis, little is known about the technical validity of this indicator. Accordingly, a literature review was conducted, which has resulted in a bibliography and synthesis of related literature.

APPROACH: The literature review consisted of searching pertinent electronic databases; reviewing pertinent articles and their cited references; reviewing recently published journals on related subjects; and reviewing references obtained from subject matter experts.

The authors found no articles specifically addressing water-stained leaves. Articles related to wetlands, however, are numerous, and investigations of decomposition continue to be relatively common. Articles that met any one of the following four criteria, listed in order of decreasing importance, were selected for inclusion in this bibliography:

- Articles dealing with water-stained leaves or comprehensive aspects of decomposition in wetlands.
- Articles dealing more generally with aquatic decomposition.
- Articles dealing with decomposition in wetlands (but not necessarily including marshes or tidal wetlands).
- Articles dealing with potentially relevant aspects of wetland ecology.

Pertinent information from the articles reviewed is summarized in Table 1, with respect to habitat type, location, process investigated, and environmental factors considered. Although no articles focused on (or even mentioned) water-stained leaves in wetlands or in any other habitat, all were relevant to an overall understanding of conditions in which water-stained leaves might or might not be expected to occur in wetlands or other habitats.

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Table 1. Annotations to bibliography. (Footnotes appear on the page following the table.)

REF	LOCATION[1]	HABITAT[2]	GENERA[3]	MAIN[4]	PHYS[5]	CHEM[6]	HYDRO[7]	EDAPH[8]	BIOL[9]	SUBST[10]
1		STR	AL	D					M	
2	GERM	STR	AC, QU	D					M Z	C
3	QUEB	PEA	BE, CX, SC, SP, SX	D		L				M
4	FL	MFW	PN, SG	B D V			W			
5	MS EMBAY	BHF		H			V			
6	IL	FRV	AC, QU	H V			W		M Z	S
7	VA	STR	PL	D						C
8		MAN, MFW, MSW	CX, JU, RZ, ST	B D S		A R				M
9	GA	MFW, SWA	CX, ST	D	T		E			M S
10	GA	SWA		D		P				S
11	LAB	TER		D				M	M	
12	LAB	MIC	PH	D	L					
13	NC	LEV, RIV, SWA	NS	D			W			
14				B D H S V	A S	N	W			
15	NETH	STR	NM	D	S			D		P
16				B D H S V			V W			
17	VA	STR	BE, CO, JU, QU	D		P			M	S
18	MI	PEA	BE, CD, CX, SX	D		A				P S
19	FRAN	STR, FOR, FRV	SX	DH	C T S	A	D			
20	LAB	STR	PI, PP	D	C	L				
21	WALE	TER	AE, FA	B S		P				
22	ENGL	STR	VARIOUS	D						A M P S
23	NC, VA	SWA	AC, CC, NS, QU, TX	D						C M S
24	LAB	SWA	AC	D H		L	V W			
25	LAB	SWA	TX	B D H		A L N P R	W			P
26	VA	SWA	AC, CC, LQ, NS, QU, TX	B D H S V		A	D V			M P S
27	LAB	STR	VARIOUS	B		N			M	S
28	AK	LAK	CX	D		N			A M Z	
29	AK	LAK	CX	D	A L T		D		M	
30	LAB		PP	D						C
31	PR	FFO	PR	B H S		A L N R	E V	A M		
32	KS	STR	CE, QU	D	C					S
33	LAB	STR	AL, SX	D		L				C M S
34	LAB	LAK	MM, NA, NU, SC	D	T	A L R				S
35	VA	SWA	AC, CC, LQ, NS, QU, TX	H V			W			
36	CO	STR	AL	B D	S	P			M Z	C
37	KS	FRV, GAL, STR		D H	S		V			S

REF	LOCATION[1]	HABITAT[2]	GENERA[3]	MAIN[4]	PHYS[5]	CHEM[6]	HYDRO[7]	EDAPH[8]	BIOL[9]	SUBST[10]
38	ARGE	RIV	EI, PN, PS	D	C		D			S
39	WALE	LAK	FA, IS, PT, SX	D	C				M Z	S
40	OH	FRV	AC, PL, PP, SX	H S V	C					
41	NH	STR		S				S	M	Q
42	TX	FRS	LU, NE, TY	D			W			P S
43	CSTL PLN	BHF	VARIOUS	S V		A R	V	M		
44	VA	FRV		H V						
45	LA	SWA	VARIOUS	B D	S	A N R				
46	ENGL	SUP	AC	D S		P			Z	C
47	LAB			D						M
48	NETH	LAK	NM	D					M Z	
49	GA	STR	AC, TX	D H					Z	S
50	ALBE	PEA	SP	D	T		D W	M		
51	LA	FOR, SWA		H V					M	
52	UT	STR	AC	D	T					
53	AK	LAK	CX	D		P			M	
54	NC, VA	SWA	AC, CC, NS, QU, TX	V			V W			
55	MI	FRV, STR	FR	D					Z	
56		SSU		B S		A N P R		A D M S		
57	GA	MSW, SWA	CX, ST	D						M S
58	TN	STR	AC	D		P			M Z	
59	LAB		FR, PE, ST	B					M	M Q
60	SWED	FEN, STR	CX	D						M
61	SWED	MFW	CX, ME, SC	V		N				M
62		SSU		S		A R		A M S		
63	MI, KS	STR	VARIOUS	D		L			M Z	A C S
64	IL	FFO, FOR	AC, CY, QU	D H			W			C S
65	ASTL	STR	CS, EU, MM, SX	D	C				Z	S
66	SC	PON	VARIOUS	V						M S Q
67		SSU		B S V		A L N P R		A D M S		
68	WI	MFW	SC, SM, TY	D	T	N				P S
69	LA	SSU		B D		N R	V			
70	OH	LAK	AC	D	T	A	D			
71	MI	STR	FR	D		A		S	M	C
72	IA	LAK	PO	D			D		Z	
73	SAFR	LAK	PT	D		N				C
74	NZEA	STR	NO	D S	C S				M Z	
75	LAB	TER		D			V	M		
76	MA	PEA	MC	D			D	M		M

REF	LOCATION[1]	HABITAT[2]	GENERA[3]	MAIN[4]	PHYS[5]	CHEM[6]	HYDRO[7]	EDAPH[8]	BIOL[9]	SUBST[10]
77	ALL US	VARIOUS	VARIOUS	H S V						
78	INDI	MFW, SSU, SUP	TY	B D			V W			P
79	SC	FFO	AC, CY, FR, LR, PL, QU, SX	V			V W			
80	SC	FFO	AC, CY, FR, LR, PL, QU, SX	B D	S	L	V			C M S
81	LAB	TER		D			V	M		
82	LAB	TER		D			V	M	M	
83	TN	PON, STR	QU	D	C L T	P			Z	
84		STR		D	T					M
85	MI	STR	CY, QU	D						M S
86	ALBE	FOR	PI, PP	D		L	V			C S
87	ALBE	FOR	PI, PP	D	T	L				C S
88	LAB	STR	AL	D	C	L				
89	TN	FOR, STR	AC, LR, QU	D	A	L	W			S
90	NSCO	STR	AC, QU	D	T	P				
91	SC	FRV, STR	NS	D	C				Z	C
92	INDI		EI	D		N			M	M
93	NC, VA	SWA	AC, CC, NS, QU, TX	D S				D M		P S
94	NC	STR	CO, QU, RD	D	A C S					
95	TN	FOR, PON, STR	AL, PL, QU	B D	AC	L	W		M	S
96	MO	LAK, FRS	NE, QU	D			W			S
97	NC, VA	SWA	AC, CC, LQ, NS, QU	B D	A		V W			S

[1]Place where research was performed. Two-letter forms are standard abbreviations for US states or commonwealths. "LAB" indicates that observations were made in the laboratory. Four-letter abbreviations represent Canadian provinces or other countries, as follows: ALBE-Alberta; ARGE-Argentina; ASTL-Australia; ENGL-England; FRAN-France; GERM-Germany; INDI-India; NETH-Netherlands; NSCO-Nova Scotia; NZEA-New Zealand; QUEB-Quebec; SAFR-South Africa; SWED-Sweden; WALE-Wales. In rare instances (e.g. 5,43), the most specific or useful notation of location is not a political jurisdiction but a physiographic region (e.g., Mississippi embayment and coastal plain, respectively).

[2]Specific habitat(s) in which this work was done, as named by the investigators: BHF-bottomland hardwood forest; FEN-fen; FFO-floodplain forest; FOR-forest, upland; FRS-floodplain, reservoir; FRV-floodplain, riverine; GAL-gallery forest; LAK-lake; LEV-levee; MAN-mangrove swamp; MIC-microbial communities; MFW-marsh, freshwater; MSW-marsh, saltwater; PEA-peatland; PON-pond; RIV-river; SSU-soil, submerged; STR-stream; SUP-soil, upland; SWA-swamp, freshwater; TER-terrestrial.

[3]AC-Acer; AE-Aesculus; AL-Alnus; BE-Betula; CC-Chamaecyparis; CD-Chamaedaphne; CE-Celtis; CO-Cornus; CS-Casuarina; CX-Carex; CY-Carya; EI-Eichhornia; EU-Eucalyptus; FA-Fagus; FR-Fraxinus; IS-Isoetes; JU-Juncus; LQ-Liquidambar; LR-Liriodendron; LU-Ludwigia; MC-Myrica; ME-Menyanthes; MM-Myriophyllum; NA-Najas; NE-Nelumbo; NM-Nymphoides; NO-Nothofagus; NS-Nyssa; NU-Nuphar; PE-Peltandra; PH-Phragmites; PI-Pinus; PL-Platanus; PN-Panicum; PO-Polygonum; PP-Populus; PR-Prestoea; PS-Paspalum; PT-Potamogeton; QU-Quercus; RD-Rhododendron; RZ-Rhizophora; SC-Scirpus; SG-Sagittaria; SM-Sparganium; SP-Sphagnum; ST-Spartina; SX-Salix; TX-Taxodium; TY-Typha.

[4]Main subjects considered by the article: B-biogeochemistry:nutrient cycling, uptake, release; D-decomposition: loss (or accumulation) of matter and individual constituents over time; H-hydrology; S-sediments and soils; V-vegetation: abundance, distribution, diversity, primary productivity.

[5]Physical factors that may influence the occurrence of water-stained leaves: A-abrasion, scouring, mechanical fragmentation; C-current, turbulence; L-light; T-temperature; S-sedimentation, siltation, burying.

[6]Chemical factors that will affect leaf appearance: A-anoxia, dissolved oxygen concentration; L-leaching from substrate; N-nutrient availability in surrounding water and soil; P-pH, acidity, anthropogenic acidification; R-redox, extent of chemical reducing conditions.

[7]Hydrological effects, especially on the presence of leaves: D-depth of water; E-export of substrate; G-groundwater; V-variability of conditions, including periodicity and seasonality, duration, frequency; W-wet, i.e., overall effect of flooding and submergence.

[8]Edaphic factors that will affect the presence and appearance of leaves: A-aeration of soil; D-depth of soil; M-moisture in soil; S-structure of soil, including composition, texture and density.

[9]Biological factors that may alter the appearance of leaves: A-algae and other primary producers; M-microorganisms, especially bacteria and fungi, other than primary producers; Z-animals.

[10]Substrate features: characteristics of the leaves themselves which will likely influence their presence and discoloration: A-age; C-condition: degree of microbial colonization, extent of leaching, presence of surficial coatings, particle size and shape, compaction in habitat; M-molecular constituents and structure: inorganic nutrients, metabolic inhibitors, structural macromolecules, sclerophylly; P-parts: differentiation of response by separate parts, e.g. leaves, petioles, stems, rhizomes; S-species-specific effects; Q-quality, with respect to lability and refractivity to degradation, suitability as a microbial substrate or animal food.

Citations are listed alphabetically by authors' names. Citation numbers key the bibliographic information to the annotations in Table 1.

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CONCLUSIONS: Although there is little technical evidence that directly relates the presence of water-stained leaves with jurisdictional wetland criteria, the frequent occurrence of these darkened leaves in wetlands and the obvious association of water-stained leaves with inundation make them an indicator worthy of further consideration. To improve the utility of water-stained leaves in the wetland delineation process, it is recommended that research be conducted to address the following preliminary questions: (1) What is the origin and composition of the color of water-stained leaves, (2) What environmental factors typically result in discoloration of leaves (e.g., moisture, redox, temperature, microbial activity) and how long does it take for leaves to become stained, (3) Are all species of leaves equally susceptible to discoloration, and (4) Is the staining process reversible?

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